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ANALYTICAL REFERENCE SERVICE TRAINING PROGRAM. WATER RADIOLOGICAL NUMBER 1, JUNE 1959

Robert A. Taft Sanitary Engineering Center
Cincinnati, Ohio

June 1959

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ANALYTICAL REFERENCE SERVICE

INTRODUCTION

The Analytical Reference Service conducted by the Sanitary Engineering Center has as its primary goal the evaluation of laboratory methods in the field of sanitary engineering. The Reference Service itself is a voluntary association of member organizations responsible for the conduct of laboratory programs The evaluations are obtained by the cooperative efforts of the members in the analysis of identical samples.

This mechanism provides:

1. A statistical evaluation of procedures, including precision and accuracy.
2. An opportunity for a participant to compare his laboratory procedures and results with other laboratories having similar responsibilities.
3. An exchange of information regarding weaknesses of currently approved methods.
4. Evidence regarding methods requiring further development or perhaps entirely new approaches.
5. A framework for broad-scale evaluation of new analytical methods.

PLAN OF OPERATION

Initially, efforts are being directed toward the chemical examination of water. The scope of the program will be broadened gradually to include other types of examinations and other media.

Using the most refined grade of chemicals available, samples are prepared containing measured amounts of the desired constituent. Decisions as to the qualitative makeup of any particular sample follow suggestions from the members and from the staff of the Sanitary Engineering Center.

After a sample is designed and prepared, a notice announcing its availability and qualitative makeup is sent with a self-addressed reply card to member organizations. An affirmative reply initiates immediate shipment of a portion of the described sample. Results are requested within some reasonable period, usually sixty days.

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REPORTING OF RESULTS AND COMMENTS

Data are returned to the Sanitary Engineering Center on forms supplied with the sample. Space is provided on the forms for numerical values and a narrative critique of analytical procedures used.

The results obtained by the cooperating laboratories are compiled as in the accompanying report. From examination of the combined data it is hoped that reliable estimates may be made of the accuracy and precision of the methods employed.

All laboratories are strongly encouraged to supply comments on the analytical methods they use. A complete log of pertinent details, including difficulties, modifications, sources of error, and other factors, is extremely valuable. Such a compilation of comments represents an exchange of ideas and opinions that is a significant part of the final report.

H. P. Kramer
Chief, Training Program

ANALYTICAL REFERENCE SERVICE MEMBERS AS OF JUNE 26, 1959

State Agencies

Alabama Water Improvement Commission
Arizona State Department of Health
Arkansas State Board of Health
California State Department of Public Health (Berkeley)
California State Department of Public Health (Los Angeles)
California Department of Water Resources
Colorado State Department of Public Health
Connecticut State Department of Health
Florida State Board of Health
State of Hawaii Department of Health
Idaho State Board of Health
Illinois State Water Survey Division
Kentucky State Department of Health
Louisiana State Health Department
Maryland State Department of Health
Maryland State Water Pollution Control Commission
Michigan State Department of Health
Minnesota State Department of Health
Missouri Department of Public Health and Welfare
Montana State Board of Health
Nebraska State Department of Health
New Hampshire Water Pollution Commission
New Jersey Department of Health
New York State Department of Health
New York State Conservation Department
North Carolina State Board of Health
Ohio State Department of Health
Oregon State Board of Health
Pennsylvania Department of Health
State of Rhode Island and Providence Plantations Dept. of Health
South Carolina State Water Pollution Control Authority
South Dakota Department of Health
New Mexico State Department of Public Health
Tennessee Stream Pollution Control Board
Texas State Department of Health
Utah State Department of Health
Vermont State Department of Health
Vermont State Water Conservation Board
Virginia State Water Control Board
Washington State Department of Health
West Virginia State Water Commission

Municipal Agencies

Metropolitan Water District of Southern California
Los Angeles Department of Water and Power
Chicago Department of Water and Sewers
Flint Department of Public Works and Utilities

Federal Agencies

Tennessee Valley Authority, Wilson Dam, Alabama (Lab I)
Tennessee Valley Authority, Wilson Dam, Alabama (Lab II)
U.S. Dept. of the Interior, Geological Survey, Sacramento, Calif.
U.S. Dept. of the Interior, Geological Survey, Denver, Colorado
U.S. Dept. of the Interior, Geological Survey, Columbus, Ohio
U.S. Dept. of the Interior, Bureau of Reclamation, Denver, Colorado
U.S. Army Environmental Health Laboratory, Maryland
Tennessee Valley Authority, Chattanooga, Tennessee
Sanitary Engineering Division, 13th Naval District
U.S. Department of the Interior, Geological Survey, Washington, D.C.

Universities

Georgia Institute of Technology, Dept. of Applied Biology
Purdue University, Department of Chemistry
Rutgers University, Department of Sanitation
Case Institute of Technology, Dept. of Civil and Sanitary Engineering
University of Pittsburgh, Graduate School of Public Health

Industry

National Aluminate Corporation
Monsanto Chemical Company

Foreign

Vancouver, B.C., Department of National Health & Welfare
Ottawa, Ontario, Department of National Health & Welfare

PARTICIPANTS IN THIS STUDY OF SAMPLE TYPE V

Arkansas State Board of Health
Army Chemical Center, Edgewood, Maryland
California State Department of Public Health (Los Angeles) *
Chicago South District Filtration Plant
Connecticut State Department of Health
Florida State Board of Health
Illinois State Water Survey Division
Kentucky State Department of Public Health
Los Angeles Department of Water and Power
Metropolitan Water District of Southern California
Michigan Department of Health
Minnesota State Department of Health
Montana State Board of Health
National Aluminate Corporation
New Hampshire Water Pollution Commission
New Jersey State Department of Health
New York State Department of Health
North Carolina State Stream Sanitation Committee
Ohio Department of Health
Pennsylvania Department of Health
U. S. Geological Survey, Columbus, Ohio
U. S. Geological Survey, Denver, Colorado
Vermont State Water Conservation Board
South Carolina State Water Pollution Control Authority
South Dakota State Department of Health

*Work Done by Consultant

LIST OF ANALYTICAL REFERENCE SERVICE SAMPLES WHICH HAVE BEEN DISTRIBUTED AND ON WHICH REPORTS HAVE BEEN COMPLETED

SAMPLE TYPE I AND IA

(Mineral, Water) analyzed for calcium, magnesium, hardness, sulfate, chloride, alkalinity, nitrite, nitrate, sodium and potassium.

SAMPLE TYPE II

(Heavy Metals, Water) analyzed for copper, cadmium, aluminum, chromium, iron, lead, manganese, and zinc.

SAMPLE TYPE III

(Fluoride, Water) analyzed for fluoride in the presence and absence of interferences with and without distillation, using a specified procedure.

SAMPLE TYPE IV

(Inorganics, Air) analyzed for chloride, sulfate, fluoride and nitrate in aqueous solution and on glass fiber hi-vol filter mats.

SAMPLES WHICH HAVE BEEN DISTRIBUTED AND WHICH ARE NOW IN THE PROCESS OF STUDY

SAMPLE TYPE VI

(Surfactant, Water) analyzed for anionic materials in distilled, tap and raw river waters.

REPORT ON SAMPLE TYPE V

I. PURPOSE OF STUDY

During the past few years, there has been an increasing need for Federal, State and municipal agencies to assess the radioactivity levels in environmental samples such as air, food, vegetation, milk and water. In most cases, it is desired to measure first the gross activity of the sample and then, where indicated, the activity of specific radionuclides. Currently, the measurement of gross activity is complicated by a number of factors such as choice of standard, technique of sample preparation, and type of instrument used for counting.

For these reasons, a natural water sample containing a measured amount of pure beta emitting radionuclide was distributed to those members of the Analytical Reference Service who indicated an interest in participating in the study.

The objectives set down were the following:

a) how accurately is radioactivity at normal or background levels being determined?

b) what factors affect accuracy?

c) is there a well-defined need for standardization of sample preparation and counting techniques?

d) does the type of instrumentation affect the results significantly?

II. PREPARATION OF SAMPLE

This first reference sample containing a radionuclide resembled a natural water sample of the type usually encountered in routine examinations, and the report form called for information concerning methods of sample preparation, counting techniques and other factors.

The sample was prepared by adding an accurately measured amount of thallium^{204} to 160 liters of Cincinnati tap water. The thallium was obtained from the National Bureau of Standards and the certificate of activity supplied

with the purchase was used as the primary standard in subsequent calculations. Preliminary determinations were made by the Radiological Health Research Activities of the Sanitary Engineering Center, the Oak Ridge National Laboratory, and the Analytical Reference Service. These referee results agreed very well with the calculated value of 5.44×10^{-7} μc/ml, and are listed below:

Oak Ridge National Laboratory.	$5.3 \pm 0.5 \times 10^{-7}$
Radiological Health Investigations, SEC. .	$5.8 \pm 0.4 \times 10^{-7}$
Analytical Reference Service, SEC. . . .	$5.6 \pm 0.1 \times 10^{-7}$

III. DISCUSSION OF RESULTS

A. Twenty-five of the 31 groups participating in the study returned results in time to be included in this report. Agency #25 submitted two reports, in which the determinations were performed independently and the results have been treated as if from different agencies. Agency #3 counted duplicate samples with an end-window instrument and a third aliquot was assayed with a windowless gas flow counter in both the proportional and Geiger regions. Since all the results from this agency were similar, only the end-window results were used in the final tabulations. All of the data from the 25 cooperating agencies are summarized in Table I.

IV. FACTORS AFFECTING THE RESULTS

The following factors were shown to be important in affecting the overall results:

1) solids drying temperature
2) type of counting instrument used
3) choice and preparation of standard
4) sample volume

These factors are arrayed and summarized in Tables II and III.

TABLE I

SUMMARY OF DATA

Number of agencies reporting	25
Number of results*	26
Amount of activity in sample*	5.44×10^{-7} µc/ml
Amount recovered, all groups, $\bar{x}$	4.13×10^{-7}
Median*	4.62×10^{-7}
Range*	-0.30 -- $+8.20 \times 10^{-7}$
50% Range*	$\pm 0.80 \times 10^{-7}$
Number of results within ± 10% of true amount*	8
Number of results within ± 50% of true amount*	20
Mean % Deviation from amount added	29.9%
Mean % Deviation within laboratories	2.8%
Standard Deviation from mean	1.84
Standard Deviation from amount added	2.27

*These results are illustrated in the probability distribution curve #1.

TABLE II

ARRAY OF FACTORS AFFECTING RESULTS

Agency #	Amount Reported $\times 10^{-7}$ μc/ml	Drying Temperature	Type Counter	Standard	Sample Volume liter
8	0.30	600°C	I.P.	C^{14}	1.0
16	0.38	**	E.W.	U_3O_8	0.5
22	1.28	450°C	E.W.	Tl^{204}	1.0
20	1.63	**	E.W.	U_3O_8	0.5
1	1.93	180°C	E.W.	Tl^{204}	0.5
24	2.91	**	E.W.	Bi^{210}	1.0
3	3.26	105°C	E.W.	K^{40}	1.0
18	3.48	**	E.W.***	K^{40}	1.0
23	3.72	103°C	E.W.***	B^{210}	0.25
5	4.13	**	I.P.	----	0.5
14	4.38	**	I.P.	Tl^{204}	0.5
11	4.53	**	I.P.	C^{14}	0.5
25	4.58	**	E.W.	Tl^{204}*	0.5
7	4.67	102°C	I.P.	U_3O_8	1.0
10	4.81	**	I.P.	C^{14}	0.5
13	4.83	165°C	I.P.	Ra D&E	0.25
12	4.95	**	I.P.	C^{14}	0.5
17	4.97	110°C	I.P.	Tl^{204}	1.0
4	5.02	**	I.P.	Ra D&E	0.5
9	5.10	103°C	I.P.	Tl^{204}*	0.2
25A	5.10	**	E.W.	Tl^{204}*	0.5
19	5.54	105°C	E.W.	Tl^{204}*	0.5
2	5.58	103°C	I.P.	Tl^{204}*	0.2
6	5.88	**	I.P.	Tl^{204}*	0.25
15	6.24	**	I.P.	----	----
21	8.23	105°C	I.P.	U_3O_8	0.2

*Used Tl^{204} in preparation of self-absorption curves

**Temperature not stated

***Thin window, gas flow counters

TABLE III

SUMMARY OF FACTORS AFFECTING RESULTS

	Radioactivity (MEAN, $\bar{x}$) $\times 10^{-7}$ μc/ml
Drying Temperature of Solids	
Greater than 165°C (4 results)	2.08
Less than 165°C (22 results)	4.50
Type of Counting Instrument	
End Window (11 results)	3.05
Internal Proportional (15 results)	4.91
Choice of Standard	
Thallium^{204} (10 results)	4.43
Other (16 results)	3.94
Thallium^{204} with self absorption curves (5 results)	5.24
Sample Volume	
1.0 liter (6 results)	2.98
0.5 liter (12 results)	3.92
Less than 0.5 liter (6 results)	5.57

1. Effect of solids drying temperature

Twelve agencies stated specifically the drying temperature of the solids. Numbers 8, 22 and 1 reported respectively 600°C, 450°C and 180°C for drying and each obtained extremely low results. Number 13 reported use of 165°C for drying temperature and obtained results greater than the mean of all groups regardless of temperature used. While drying of dissolved solids at elevated temperature for moisture removal is a traditional and acceptable procedure, a temperature of not more than 110°C is usually recommended to prevent volatilization of the solids. This same recommendation holds for fission products, since thallium loss is appreciable at temperatures above 165°C, whereas no appreciable loss is observed at temperatures of 110°C.

2. Effect of type of counting instrument used

It has been pointed out in several publications,[1, 2] that certain disadvantages are inherent in end-window counting resulting primarily in low, variable counting efficiency.

The majority of low results in this study were obtained using either end-window or modified end-window counters. Indeed, the mean result of all end-window data was 3.05×10^{-7} μc/ml as contrasted to a mean of 4.91×10^{-7} μc/ml for internal proportional instruments. On the other hand, the results obtained by groups #19 and 25A indicate that with proper usage, end-window counters are entirely capable of furnishing accurate and precise values.

3. Effect of choice and preparation of standard

Some laboratories have apparently used standards only for obtaining a plateau curve for the instrument; others have used a single standard for the calibration of the instrument for a single sample thickness; still others have prepared multiple standards for comparison with samples of various thicknesses. The latter procedure should provide the highest accuracy. Selection of a radionuclide standard having energy properties similar to the unknown is also necessary for accurate results. As might be expected, those laboratories using thallium^{204} standards for measurement of efficiency factors under

1. Setter, L.R., and Goldin, A.S., "Measurement of Low Level Radioactivity in Water", Jour. AWWA, 48:11 p 1373 (1956).

2. Setter, L.R., Nader, J.S., and Hagee, G.R., "Limitations in the Use of the End-Window Counter in Assaying Stream Water for Beta Radioactivity", U.S. AEC Documents, #Wash-129, p 166 (1953).

varying thickness conditions proved to be the most accurate, yielding a mean of 5.24×10^{-7} μc/ml. For those using thallium^{204} as a "standard", the mean result was a 4.43×10^{-7} μc/ml, whereas those using other standards averaged 3.94×10^{-7} μc/ml.

4. Effect of sample volume

Of the 26 agencies reporting, 7 used volumes of 1000 ml, 12 used 500 ml and the remainder used 250 or 200 ml samples. (One used three different volumes and its results are not considered in this discussion). On the basis of volume, the data yields a mean of 2.98×10^{-7} μc/ml for those using 1 liter, 3.92×10^{-7} μc/ml for those using 0.5 liter and 5.57×10^{-7} μc/ml for those using less than 0.5 liter. Thus self-absorption or loss of solids in sample preparation are more significant in counting rate reduction than is usually recognized. With a smaller sample volume, there is less loss of activity either by volatilization or by loss of solids during transfer. A smaller weight of solid material in the counting planchet may be important in obtaining more reliable self-absorption factors.

V. FACTORS WHICH DID NOT AFFECT THE RESULTS

Factors whose influence upon the result were not apparent are: type of acid used for wash solution, type of planchet used for solids containment, method of drying solids other than ignition, and total solids recovery. Regarding the latter, a high total solids result implies high efficiency in transfering the solids into the counting planchet. No apparent correlation, however, exists between the total solids and the results reported.

VI. REPORTING AND COMPUTATIONAL ERRORS

Examination of the data reported by the Analytical Reference Service members revealed a number of errors having no connection with sample preparation and counting but which, if undetected might have significantly affected the final results. In most cases, these errors were reported to the appropriate member and the corrected results used as the "amount reported".

Eleven agencies reported results having significant computational errors. Four reported incorrect exponential figures or did not relate concentration with a specific volume. Two did not incorporate self-absorption factors into the calculations although such factors were included on the report form. Three had errors in calculating the thickness of the total dissolved solids and two had errors in arithmetic. One of the latter occurred in subtraction of background count from gross count and the other from use of an incorrect sample volume factor.

Three agencies committed procedural errors which they later corrected. One detected erratic instrumental counting after its report had been received by the Analytical Reference Service. After the instrument had been repaired, a second and much improved report was submitted. Another noted unsatisfactory results and submitted a second report after the solids had been dried in a satisfactory manner. Still another reported that the use of an incorrect half-life for thallium^{204} had materially affected its final calculation.

If these errors had not been recognized, almost half of the final results in this report would be affected. Since most of these errors are not due to actual operational procedures, they are not included in the summary of results. Computations associated with radioactivity measurements proved to be a significant potential source of error.

VII. RELATIONSHIP OF FACTORS TO EACH OTHER

The significance of the factors such as temperature, choice of instrument, choice of standard and sample size have been discussed in the preceeding paragraphs. These variables have been considered as entities and no emphasis has been placed upon the relationship of the variables to each other. An attempt to do this was made by categorizing the results according to instrument versus volume versus standard. The final tabulation gave too few results in any category to be statistically significant. Those agencies which obtained the more accurate results employed the follow-procedure:

1) used a sample of 500 ml or less
2) dried the dissolved solids at a temperature of 103-110^{o}C
3) corrected for self-absorption by use of Tl^{204} in varying amounts of dissolved solids
4) used internal proportional instruments for counting the samples

VIII. SUMMARY AND CONCLUSIONS

The conclusions reached on the basis of this study regarding accuracy of activity measurements are drawn from Table II and Curve #1, namely that half of the Analytical Reference Service members who participated could obtain results within 15% (0.8×10^{-7} μc/ml) of the true amount. The standard deviation from amount added for all results on this sample was 2.27.

The most pertinent factors influencing these results have been discussed and point to the necessity for a well-defined technique in assaying levels

of radioactivity. The effect of instrumentation has also been discussed, but it should be reiterated that the end-window counters require more careful and skillful use in attainment of good results.

IX. PLANS FOR FUTURE STUDIES

The data presented reflect the many variables in the techniques currently being utilized in the preparation and counting of water samples. To reduce these somewhat and to enable closer statistical evaluation of reported data, it will be necessary to make certain recommendations on techniques employed in analyzing samples of this type distributed in the future.

Thallium-204 served as the source of radioactive material in Sample Type V (Water, Rad.) because this material had been recommended[1] and widely used as a standard in measuring mixtures of radionuclides of unknown identity. Thallium-204 however, because of its volatility, lack of gamma emissions, and ill defined half-life, leaves much to be desired. This has led several authorities in the field to suggest $Cs^{137}(+Ba^{137m})$, which releases gamma as well as beta radiations, as a more appropriate standard. This nuclide, for example, has been designated by ASTM Committee D-19 on Industrial Water as the standard in their tentative method for "Measurement of Gamma Radioactivity of Industrial Water and Industrial Waste Water".[2] It is contemplated, therefore, that Cs^{137} will serve as the radioactive source in the next Type V (Water, Rad.) sample distributed by the Analytical Reference Service.

REFERENCES:

1. Wheler, A.G., Jr., Reynolds, S.A., and Brooksbank, W.A., Jr., "Thallium as a Reference Standard for Beta Radioactivity", Journal AWWA, 46:1 pp 79-81 (January, 1954).

2. American Society for Testing Materials, "Annual Report of Committee D-19 on Industrial Water", Max Hecht, Chairman, Annual Meeting Atlantic City, N.J. (June 21-26, 1959).

ARS - SAMPLE TYPE V

SUMMARY OF LABORATORY PROCEDURES

Agency #	Sample Volume	Evap. Procedure	Planchet
8	1000	*	Stainless steel 5.0 cm
16	500	*	Stainless steel 2.5 cm
22	1000	Beaker	Stainless steel 2.5 cm
20	500	*	Stainless steel 2.5 cm
1	500	Evap. Dish Steam	Aluminum 3.6 cm
24	1000	Beaker, Oven	Stainless steel 2.5 cm
3	1000	Evap. Dish Steam	Aluminum 3.2 cm
18	1000	Evap. Dish Steam	Stainless steel 5.0 cm
23	250	Beaker, Steam	Stainless steel 2.6 cm
5	500	Evap. Dish	------ 5.7 cm

Wash Solution	Solids Treatment	Total Solids	Thickness - mg/cm^2
---	Ignited 600°C	89	4.4
		90	4.4
		72	3.6
---	Hot Plate	185	18.3
		185	18.3
		185	18.3
Distilled Water	Ignited 450°C	141	28
		145	28
		139	28
---	Hot Plate	185	18.3
		185	18.3
		185	18.3
1:1 HNO_3	Oven 180°C	197	9.9
		196	9.9
		199	10.0
Distilled Water	I.R. Lamp	165	33
		164	33
		172	34
Distilled Water	Oven 105°C	177	22
		172	22
		174	22
10% HCl + 1% SLS	I.R. Lamp	239	12.3
		241	12.3
		242	12.3
Distilled Water	I.R. Lamp	190	6.4
	Oven, 103°C	194	6.4
		---	---
Distilled Water	I.R. Lamp	186	7.4
		190	7.6
		192	7.7

Agency #	Sample Vdume	Evap. Procedure	Planchet
14	500	Beaker, Hot Plate	Stainless steel 3.2 cm
11	500 500 250	Beaker, Steam	Stainless steel 4.8 cm
25	500 500 350	Pt. Dish, Steam	Aluminum 3.5 cm
7	1000	Beaker, Hot Plate	Aluminum 5.0 cm
10	500	*	Aluminum 5.0 cm
13	250	*	Aluminum 4.8 cm
12	500 300 200	Beaker, Hot Plate	Stainless steel 5.0 cm
17	1000	Beaker, Hot Plate	Stainless steel 5.0 cm
4	500	Beaker, Oven	Stainless steel 5.0 cm
9	200	Beaker, Hot Plate	Aluminum 5.0 cm

Wash Solution	Solids Treatment	Total Solids	Thickness - mg/cm^2
2 N HNO_3	Hot Plate Approx. 130°C	147	9.1
		152	9.4
		166	10.2
1% HNO_3	Oven	217	6.0
		217	6.0
		228	3.2
Conc. HNO_3 Conc. HF H_2O	I.R. Lamp	200	10.4
		190	9.3
		200	7.3
1N HNO_3	Oven 120°C	196	10.0
		271	13.8
		243	12.4
1% HNO_3	Oven 103°C	196	2.0
		198	2.0
		196	2.0
Distilled Water	Oven 165°C	170	2.1
		198	1.6
		196	2.4
1N HNO_3	Hot Plate	194	4.8
		194	2.9
		220	2.2
2N HNO_3	I.R., Oven 115°C	148	7.6
		198	10.1
		195	10.0
Conc. HNO_3	I.R., Oven 105°C	215	11
		215	11
		215	11
1N HNO_3	Oven 103°C	226	2.3
		250	2.6
		236	2.5

Agency #	Sample Volume	Evap. Procedure	Planchet
25A	500 500 350	Pt. Dish, Steam	Aluminum 3.5 cm
19	1000 500 500	Beaker, Steam	Stainless steel 2.5 cm
2	200	*	Aluminum 5.0 cm
6	250	*	Aluminum 4.6 cm
15	1000 1000 500	Beaker, Hot Plate	Stainless steel 5.1 cm
21	1000	Beaker, Hot Plate	Stainless steel 5.2 cm

*Sample evaporated to dryness in planchet

Wash Solution	Solids Treatment	Total Solids	Thickness - mg/cm^2
Conc. HNO_3	I. R. Lamp	200	10.4
Conc. HF		190	9.3
H_2O		200	
2N HNO_3	Oven	200	39.4
	105°C	205	20.3
		207	20.5
1% HNO_3	Oven	186	2.0
	103°C	198	2.0
		196	2.0
----	Hot Plate	168	2.5
		162	2.4
		174	2.6
2N HNO_3	Hot Plate	184	9.3
		172	8.7
		178	4.4
Acetic	I. R.,	255	2.5
	Oven	232	2.3
	105°C	229	2.2

ARS - SAMPLE TYPE V

SUMMARY OF INSTRUMENTATION

Agency #	Type Instrument	Standard	Counting Eff., %
8	I. P.	C^{14}	60
16	E. W.	U_3O_8	18. 2
22	E. W.	Tl^{204}	4. 9
20	E. W.	U_3O_8	18. 2
1	E. W.	Tl^{204}	137
24	E. W.	Bi^{210}	5. 5
3	E. W.	K^{40}	16
18	Thin Window (Gas flow)	K^{40}	19. 6
23	Thin Window (Gas flow)	Bi^{210}	45
5	I. P.	----	53
14	I. P.	Tl^{204}	39
11	I, P.	C^{14}	47
25	E. W. (Gas flow)	Tl^{204}	27
7	I. P.	U_3O_8	39
10	I, P.	C^{14}	42
13	I. P.	Ra D+E Tl^{204}	54
12	I. P.	C^{14}	56
17	I. P.	Tl^{204}	51. 3
4	I. P.	Ra DEF	49
9	I. P.	Tl^{204}	40

Agency #	Type Instrument	Standard	Counting Eff., %
25A	E.W.	Tl^{204}	---
19	E.W.	Tl^{204}	5
2	I.P..	Tl^{204}	62
6	I.P.	Tl^{204}	35
15	I.P.	-----	46.7
21	I.P.	U_3O_8	43.4

ANALYTICAL REFERENCE SERVICE, SAMPLE TYPE V

SUMMARY OF COUNTING

Lab #	Date Counted	Gross Beta (cpm)	Time (Min.)	Background (cpm)	Time (Min.)
8	9/24	106	30	65	30
		102	30	48	30
		83	30	65	30
16	9/19	34.5	475	27.4	450
		35.0	468	27.4	450
		36.5	449	29.1	475
22	10/20	2084	120	2184	141
		3102	169	2666	170
		1061	62	465	30
20	10/9	55.7	297	27.3	600
		58.3	281	27.3	600
		59.2	278	27.3	600
1	9/12	44.0	120	21.7	120
		53.3	120	22.7	120
		52.9	120	21.4	120
24	11/14	43.6	91.8	11.2	265.3
		43.7	91.6	11.2	265.3
		45.2	88.4	11.2	265.3
3	9/12	134	30	16.6	30
		135	30	16.2	30
		134	30	16.2	30
18	12/1	146	12.3	11.9	101
		151	11.9	11.9	101
		158	11.4	11.9	101
23	11/15	103	390	16.0	250
		99.5	402	16.0	250
		---	---	---	---
5	9/18	287	30	60.6	30
		290	30	60.6	30
		301	30	60.6	30

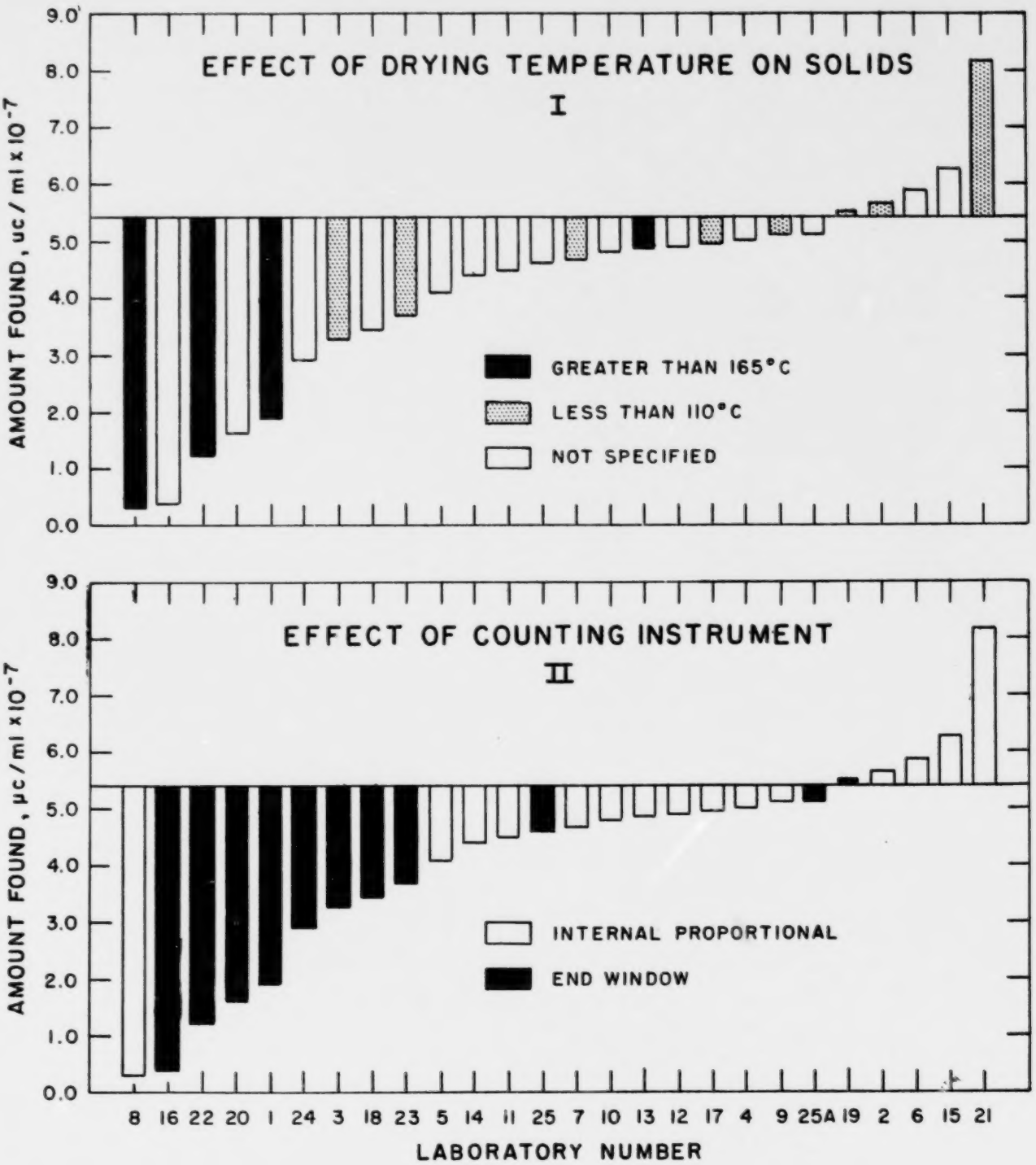
Net Beta (cpm)	DPM	Activity, μc/ml x 10^{-7}		Mean
		Reported	Corrected to 6/8/58	
41	18.5	0.31	0.33	
54	24.3	0.41	0.43	
18	8.1	0.13	0.14	0.30
7.0	38.4	0.35	0.37	
7.6	41.8	0.35	0.37	
7.4	40.7	0.37	0.39	0.38
1.9	210	1.0	1.06	
2.7	318	1.4	1.49	
1.6	---	---	---	1.28
28.4	156	1.4	1.48	
31.0	170	1.6	1.70	
31.9	175	1.6	1.70	1.63
22.3	163	1.47	1.54	
30.6	223	2.01	2.10	
31.5	230	2.07	2.16	1.93
32.4	590	2.66	2.86	
32.5	592	2.67	2.87	
34.0	619	2.79	3.00	2.91
117	687	3.09	3.23	
119	700	3.15	3.29	
118	694	3.12	3.26	3.26
134	685	3.09	3.34	
139	709	3.20	3.46	
146	743	3.35	3.63	3.48
86.7	---	3.51	3.79	
83.5	---	3.38	3.65	
---	---	---	---	3.72
226	424	3.84	4.04	
229	427	3.88	4.08	
240	450	4.06	4.27	4.13

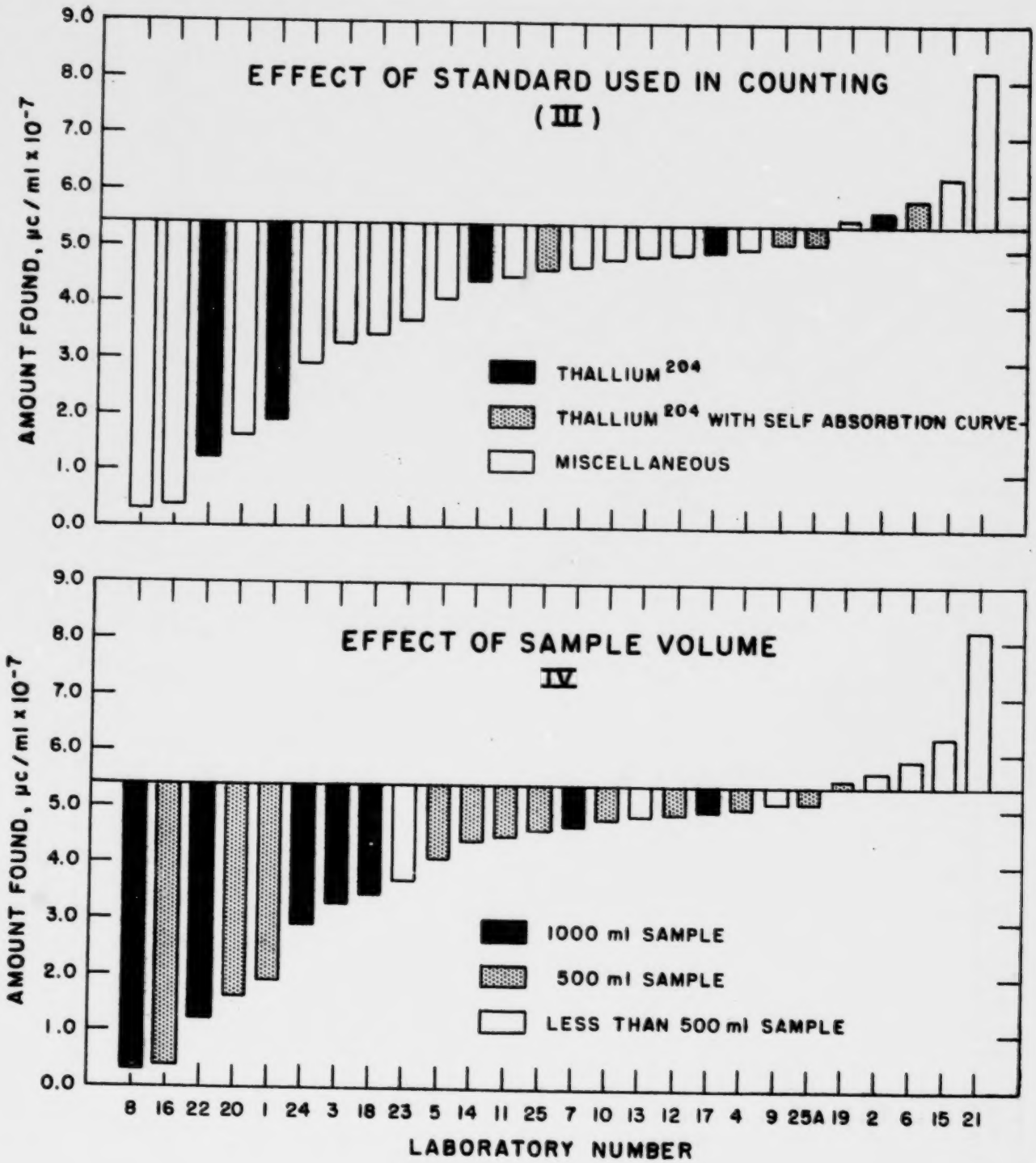
Lab #	Date Counted	Gross Beta (cpm)	Time (Min.)	Background (cpm)	Time (Min.)
14	9/19	167	240	14.9	26.8
		149	268	14.9	26.8
		180	222	14.9	26.8
11	9/26	277	30	78.8	30
		223	30	83.9	30
		314	30	78.8	30
25	2/26	89.7	30	31.5	100
		89.2	30	35.5	100
		69.8	30	31.6	100
7	9/19	453	16	33	16
		409	16	32	16
		400	16	32	16
10	9/16	287	30	47	30
		278	30	47	30
		309	30	47	30
13	9/20	172	60	35.1	--
		170	20	27.0	--
		165	40	29.5	--
12	9/17	154	20.	26.5	20
		190	20	26.5	20
		315	20	26.5	20
17	9/25	521	10	46.8	40
		553	10	46.8	40
		553	10	46.8	40
4	9/22	310	60	55	30
		314	60	55	30
		314	60	55	30
9	10/3	179	20	64.4	20
		178	20	64.4	20
		177	20	64.4	20
25A	2/25	154	126	4.2	1091
		134	126	4.2	1091
		111	126	4.2	1091

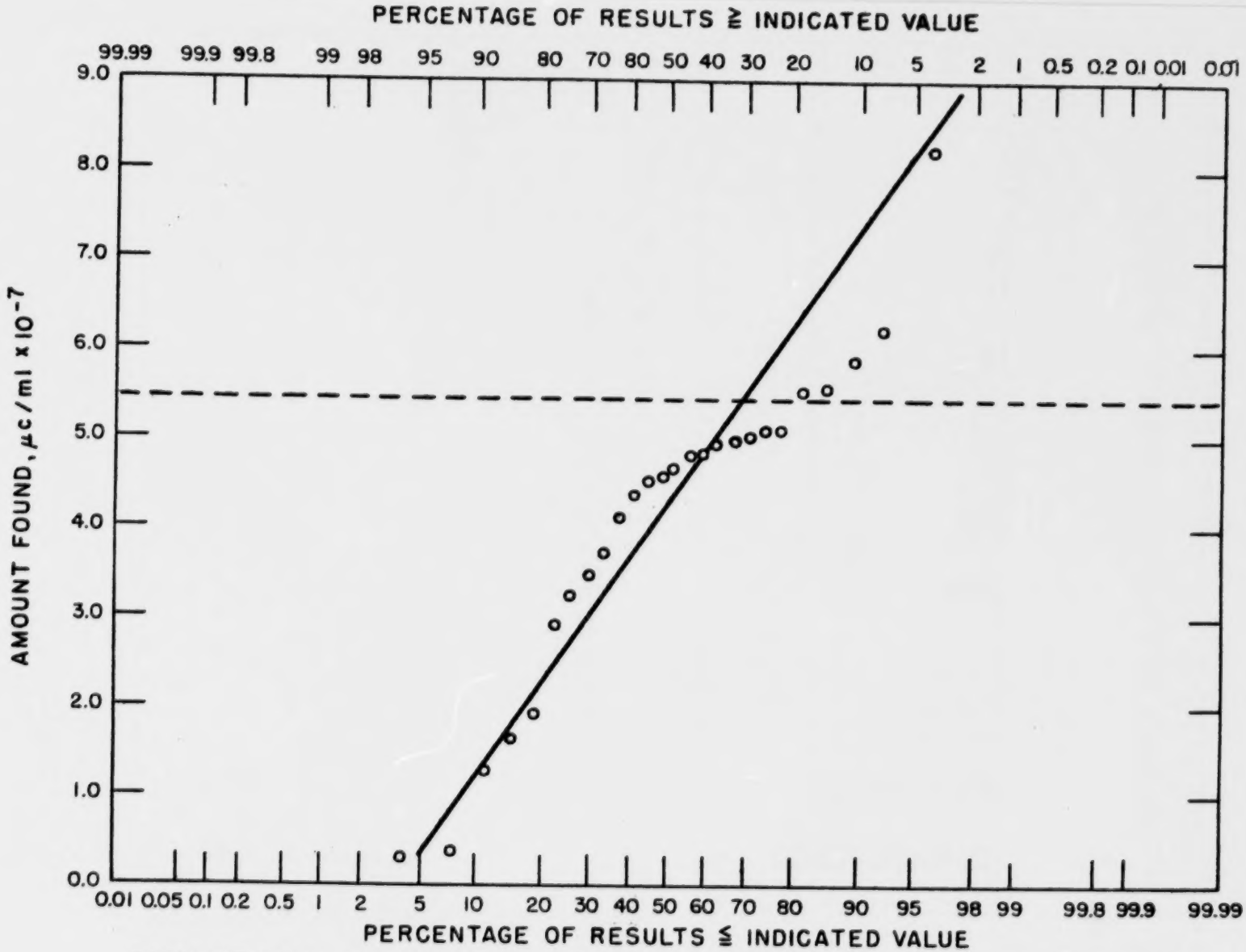
Net Beta (cpm)	DPM	Activity, μc/ml x 10^{-7} Reported	Activity, μc/ml x 10^{-7} Corrected to 6/8/58	Mean
152	381	4.15	4.36	
134	341	3.70	3.89	
165	430	4.64	4.88	4.38
199	582	3.79	3.99	
139	410	4.64	4.89	
234	659	4.48	4.72	4.53
58.2	485	4.40	4.95	
53.7	448	4.00	4.50	
38.2	294	3.80	4.28	4.58
470	450	4.50	4.73	
598	447	4.47	4.70	
584	436	4.36	4.59	4.67
240	500	4.50	4.71	
231	482	4.34	4.54	
263	548	4.94	5.17	4.81
137	252	4.55	4.79	
143	258	4.65	4.89	
135	254	4.58	4.82	4.83
128	217	4.90	5.12	
163	286	4.30	4.50	
289	555	5.00	5.23	4.95
475	911	4.40	4.64	
506	1000	4.87	5.14	
506	1000	4.87	5.14	4.97
255	523	4.70	4.95	
259	532	4.80	5.06	
259	532	4.80	5.06	5.02
115	287	4.84	5.14	
113	283	4.80	5.10	
112	281	4.76	5.06	5.10
150	549	4.50	5.07	
130	477	4.30	4.84	
107	377	4.80	5.40	5.10

Lab #	Date Counted	Gross Beta (cpm)	Time (Min.)	Background (cpm)	Time (Min.)
19	11/22	55.4	35.5	19.2	40.6
		55.3	53.1	19.3	107.1
		78.0	36.3	19.2	40.6
2	10/3	208	16	60.0	16
		189	16	61.0	16
		209	16	62.5	16
6	9/10	162	30	52	30
		158	30	52	30
		163	30	52	30
15	9/19	490	30	55	40
		481	30	57	40
		86.2	30	57	40
21	9/25	198	3/32	48.6	1060
		204	3/32	48.6	1058
		195	3/32	48.6	1058

Net Beta (cpm)	DPM	Activity, $\mu c/ml \times 10^{-7}$		Mean
		Reported	Corrected to 6/8/58	
36.2	586	5.3	5.74	
36.0	584	5.25	5.69	
58.8	1265	5.70	6.18	5.54
148	239	5.4	5.72	
128	225	5.1	5.41	
147	234	5.3	5.62	5.58
110	310	5.66	5.91	
107	304	5.52	5.76	
111	314	5.72	5.97	5.88
435	837	7.6	7.90	
424	968	4.4	4.58	
29.4	66	---	---	6.24
150	345	7.76	8.19	
155	357	8.05	8.49	
146	337	7.59	8.01	8.23


EFFECT OF DRYING TEMPERATURE ON SOLIDS
I
AMOUNT FOUND, uc / ml x 10⁻⁷
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
GREATER THAN 165°C
LESS THAN 110°C
NOT SPECIFIED
EFFECT OF COUNTING INSTRUMENT
II
AMOUNT FOUND, µc / ml x 10⁻⁷
INTERNAL PROPORTIONAL
END WINDOW
8 16 22 20 1 24 3 18 23 5 14 11 25 7 10 13 12 17 4 9 25A 19 2 6 15 21
LABORATORY NUMBER


EFFECT OF STANDARD USED IN COUNTING
(III)
AMOUNT FOUND, μc / ml x 10⁻⁷
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
THALLIUM 204
THALLIUM 204 WITH SELF ABSORBTION CURVE
MISCELLANEOUS
EFFECT OF SAMPLE VOLUME
IV
AMOUNT FOUND, μc / ml x 10⁻⁷
1000 ml SAMPLE
500 ml SAMPLE
LESS THAN 500 ml SAMPLE
8 16 22 20 1 24 3 18 23 5 14 11 25 7 10 13 12 17 4 9 25A 19 2 6 15 21
LABORATORY NUMBER



ANALYTICAL REFERENCE SERVICE SAMPLE TYPE V (WATER, RAD.)
CONTAINING 5.44×10^{-7} µc/ml OF Tl^{204}